

## CLAIMS

What is claimed:

1. A programmable material consolidation apparatus, comprising:  
a retention system including a support surface for supporting at least one substrate on or adjacent to which one or more objects are to be formed and configured to prevent lateral movement of the at least one substrate.
2. The programmable material consolidation apparatus of claim 1, further comprising:  
a selective material consolidation system configured to form the object.
3. The programmable material consolidation apparatus of claim 1, wherein the retention system includes:  
at least one raised element around at least a portion of a periphery of the support surface.
4. The programmable material consolidation apparatus of claim 3, wherein the at least one raised element is configured to prevent lateral movement of the at least one substrate.
5. The programmable material consolidation apparatus of claim 3, wherein the at least one raised element extends around an entire extent of the periphery of the support surface.
6. The programmable material consolidation apparatus of claim 5, wherein the retention system comprises at least one access element.
7. The programmable material consolidation apparatus of claim 6, wherein the at least one access element facilitates removal of the at least one substrate from a receptacle formed by the support surface and the at least one raised element of the retention system.

8. The programmable material consolidation apparatus of claim 6, wherein the at least one access element comprises at least one recess in at least an interior portion of the at least one raised element.

9. The programmable material consolidation apparatus of claim 3, wherein the at least one raised element is secured to the support surface adjacent to the periphery thereof.

10. The programmable material consolidation apparatus of claim 9, wherein the at least one raised element comprises cured photopolymer.

11. The programmable material consolidation apparatus of claim 9, wherein the at least one raised element comprises a plurality of at least partially superimposed, contiguous, mutually adhered layers.

12. The programmable material consolidation apparatus of claim 3, further comprising:  
a planarization element configured to be drawn across a surface of unconsolidated material located over at least a portion of the at least one substrate and within an interior of a periphery defined by the at least one raised element.

13. The programmable material consolidation apparatus of claim 12, wherein the at least one raised element is configured to substantially confine a volume of unconsolidated material within the interior of the periphery defined thereby.

14. The programmable material consolidation apparatus of claim 12, wherein the retention system further includes at least one extension element positioned on the at least one raised element to increase an effective height of the at least one raised element.

15. The programmable material consolidation apparatus of claim 14, wherein the at least one extension element comprises an extension ring.

16. The programmable material consolidation apparatus of claim 14, wherein the at least one extension element increases a volume of the interior of the periphery defined by the at least one raised element.

17. The programmable material consolidation apparatus of claim 12, wherein an upper surface of the at least one raised element defines a level at which the planarizing element is translated across the surface of the unconsolidated material.

18. The programmable material consolidation apparatus of claim 12, wherein the planarization element comprises a meniscus blade.

19. The programmable material consolidation apparatus of claim 12, wherein the planarization element comprises an air knife.

20. The programmable material consolidation apparatus of claim 1, wherein the retention system comprises at least one alignment feature.

21. The programmable material consolidation apparatus of claim 20, wherein the at least one alignment feature engages or abuts a corresponding feature of the at least one substrate.

22. The programmable material consolidation apparatus of claim 1, wherein the retention system includes:

at least one sealing element at the support surface thereof.

23. The programmable material consolidation apparatus of claim 22, wherein the at least one sealing element is positioned to underlie at least a periphery of the at least one substrate.

24. The programmable material consolidation apparatus of claim 23, wherein the at least one sealing element comprises an annular member.

25. The programmable material consolidation apparatus of claim 22, wherein the at least one sealing element is configured to prevent unconsolidated material from contacting a lower surface of the at least one substrate when the at least one substrate is positioned over the support surface.

26. The programmable material consolidation apparatus of claim 22, wherein the at least one sealing element comprises a compressible, resilient member.

27. The programmable material consolidation apparatus of claim 22, wherein the retention system further includes:

at least one pressure port formed in the support surface and located within an interior defined by the at least one sealing element.

28. The programmable material consolidation apparatus of claim 27, further comprising:

at least one pressure source in communication with the at least one pressure port.

29. The programmable material consolidation apparatus of claim 28, wherein the at least one pressure source comprises a negative pressure source.

30. The programmable material consolidation apparatus of claim 28, further comprising:

an ejection element which also includes the at least one pressure port.

31. The programmable material consolidation apparatus of claim 30, wherein the at least one pressure source comprises a positive pressure source.

32. The programmable material consolidation apparatus of claim 31, wherein the at least one pressure port is configured and oriented to facilitate a circulating air flow over support surface.

33. The programmable material consolidation apparatus of claim 30, wherein the ejection element is configured to facilitate grasping of the at least one substrate positioned over the support surface.

34. The programmable material consolidation apparatus of claim 28, further comprising:  
at least one control element for controlling at least one of operation of the at least one pressure source and communication between the at least one pressure source and the at least one pressure port of the retention element.

35. The programmable material consolidation apparatus of claim 1, further comprising an ejection element.

36. The programmable material consolidation apparatus of claim 35, wherein the ejection element is configured to facilitate removal of the at least one substrate from the retention component.

37. The programmable material consolidation apparatus of claim 35, wherein the ejection element is configured to break a seal between the at least one substrate and the support surface.

38. The programmable material consolidation apparatus of claim 35, wherein the ejection element includes:  
at least one recess formed in the support surface;  
at least one piston configured to be retained within the recess; and

at least one actuator associated with the at least one piston so as to cause at least a portion of the at least one piston to exit the at least one recess and to protrude from the support surface.

39. The programmable material consolidation apparatus of claim 38, further comprising:

at least one control element in communication with the at least one actuator of the ejection element.

40. The programmable material consolidation apparatus of claim 35, wherein the ejection element includes:

at least one pressure port formed in the support surface; and

a positive pressure source in communication with the at least one pressure port.

41. The programmable material consolidation apparatus of claim 40, wherein the at least one pressure port is configured and oriented to facilitate a circulating air flow over the support surface.

42. The programmable material consolidation apparatus of claim 40, further comprising:

at least one control element for controlling at least one of operation of the positive pressure source and communication between the positive pressure source and the at least one pressure port of the ejection element.

43. The programmable material consolidation apparatus of claim 1, wherein the retention element includes:

a locking ring including a side wall configured to surround at least a portion of a periphery of the at least one substrate upon positioning of the at least one substrate on the support surface.

44. The programmable material consolidation apparatus of claim 43, wherein the locking ring includes a lip which extends laterally and inwardly from an upper end of the side wall thereof.

45. The programmable material consolidation apparatus of claim 44, wherein the lip is configured to cover at least a peripheral portion of a surface of the at least one substrate.

46. The programmable material consolidation apparatus of claim 44, wherein the retention element further includes:

at least one spacer positioned on the support surface within an interior of the locking ring.

47. The programmable material consolidation apparatus of claim 46, wherein combined thicknesses of the at least one spacer and the at least one substrate are substantially the same as a height of the side wall of the locking ring.

48. The programmable material consolidation apparatus of claim 46, wherein the at least one spacer is configured to prevent unconsolidated material from contacting at least a portion of a lower surface of the at least one substrate and a portion of the support surface of the retention element.

49. The programmable material consolidation apparatus of claim 44, wherein the retention element further includes:

at least one extension ring positioned on the lip.

50. The programmable material consolidation apparatus of claim 4, further comprising:

a planarization element configured to be drawn across a surface of unconsolidated material located over at least a portion of the at least one substrate and within an interior of a periphery defined by the lip of the locking ring.

51. The programmable material consolidation apparatus of claim 50, wherein the lip is configured to substantially confine a volume of unconsolidated material within the interior of the periphery defined thereby.

52. The programmable material consolidation apparatus of claim 50, wherein the retention system further includes at least one extension element positioned on the lip to increase an effective height of the lip.

53. The programmable material consolidation apparatus of claim 52, wherein the at least one extension element increases a volume of the interior of the periphery defined by the lip.

54. The programmable material consolidation apparatus of claim 50, wherein an upper surface of the lip defines a level at which the planarization element is translated across the surface of the unconsolidated material.

55. The programmable material consolidation apparatus of claim 50, wherein the planarization element comprises a meniscus blade.

56. The programmable material consolidation apparatus of claim 50, wherein the planarization element comprises an air knife.

57. A programmable material consolidation apparatus, comprising:  
a support surface configured to receive at least one substrate on which programmed consolidation of unconsolidated material is to be effected;  
a selective material consolidation system directed toward the support surface for effecting the programmed consolidation to form at least one object on or adjacent to the at least one substrate; and  
an ejection element associated with the support surface for facilitating removal of the at least one substrate from the support surface following the programmed consolidation.



58. The programmable material consolidation apparatus of claim 57, wherein the ejection element is configured to break a seal between the at least one substrate and the support surface.

59. The programmable material consolidation apparatus of claim 57, wherein the ejection element includes:

at least one recess formed in the support surface;

at least one piston configured to be retained within the recess; and

at least one actuator associated with the at least one piston so as to cause at least a portion of the at least one piston to exit the at least one recess and to protrude from the support surface.

60. The programmable material consolidation apparatus of claim 59, further comprising:

at least one control element in communication with the at least one actuator of the ejection element.

61. The programmable material consolidation apparatus of claim 57, wherein the ejection element includes:

at least one pressure port formed in the support surface; and

a positive pressure source in communication with the at least one pressure port.

62. The programmable material consolidation apparatus of claim 61, wherein the at least one pressure port is configured and oriented to facilitate a circulating air flow over the support surface.

63. The programmable material consolidation apparatus of claim 61, further comprising:  
at least one control element for controlling at least one of operation of the positive pressure source and communication between the positive pressure source and the at least one pressure port of the ejection element.